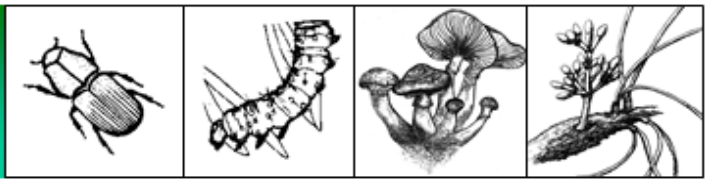
Forest Health Protection



18-08 *DECEMBER, 2018*

2018 Revised R1 Forest Insect Hazard Rating System User Guide for use with Inventory Data Stored in FSVeg and/or Analyzed with the Forest Vegetation Simulator (FVS)

Carol Randall[1], Brytten Steed[2], Joel Egan[2], Renate Bush[3] and Natalie Morgan[4]

[1] Forest Entomologist, Forest Health Protection, Coeur d'Alene, Idaho
[2] Forest Entomologists, Forest Health Protection, Missoula, Montana
[3] Regional Inventory Specialist, Renewable Resource Management, Missoula, MT
[4] Regional Inventory Analyst, Renewable Resource Management, Missoula, MT

INTRODUCTION

Forest insects and diseases are important disturbance factors in forest ecosystems. Insect and disease activity may dramatically alter the structure, composition, and age class distribution of forested stands and may interfere with a manager's ability to achieve established objectives.

As part of the Northern Region (R1) Integrated Restoration and Protection Strategy, Forest Health Protection (FHP) entomologists devised bark beetle and defoliator hazard ratings for inventory data, such as from stand exams and Forest Inventory and Analysis (FIA) plots. These hazard ratings are available to assist land managers in three ways: 1) they are keyword files that can be used with the Forest Vegetation Simulator (FVS) to determine current hazard and model hazards over time, with or without management or disturbances; 2) are calculated during the post-load process and stored in FSVeg tables; and 3) ratings are available in the R1 Summary Database Analysis tools. This document discusses forest insect hazard ratings, how they are derived, and how they may be used to assist land managers with planning.

Since the original publication of this report (Randall and Bush 2010), modifications were made to the mountain pine beetle in lodgepole pine hazard rating logic, and a combined host pine beetle hazard rating was developed (Randall et al. 2011). Further modifications were completed since the 2011 update to clarify that a minimum 40 square feet of basal area of host type is required for a hazard rating to be assigned (see Appendix 9 for justification of this criteria).

United States Department of Agriculture	Forest Service	Northern Region	Region One 26 Fort Missoula Rd Missoula, MT 59804-7203	

Hazard Ratings

Forest insects require three things to cause significant impact to resource values: susceptible hosts; insect populations; and favorable weather conditions. Hazard rating systems measure the susceptibility of forested areas to a particular insect by evaluating the degree to which sampled tree and stand-level characteristics are conducive to successful insect colonization and reproduction. High and moderate hazard forested areas are more likely to experience significant mortality if challenged by insect populations when weather conditions are favorable.

Data Considerations

When using hazard ratings in a landscape analysis (broad- [Regional assessments], mid- [Forest assessment], and base- [one to several stands] levels) (Nelson et al. 2015), it is assumed that available data are a representative sample of landscape conditions. A spatially balanced inventory across the geographic area of interest can be used to derive estimates of hazard, however, small forested areas, or areas with unique characteristics, may not be represented or have insufficient data for analysis. Users should carefully evaluate available data for a particular analysis area to insure that a representative sample of current forest conditions exists. Hazard ratings calculated for a sampled area assumes that forest conditions in the sample area are homogeneous; if excessive variability in any of the parameters used to calculate hazard ratings occurs within the sampled area, the hazard rating may not accurately reflect the hazard. If that is the case, further stratification of the geographic area of interest into various dominance types, size classes, and densities may be needed.

Hazard ratings applied to stand exams will accurately reflect the stand at time of inventory. It is important to consider the age of the exam data when interpreting hazard. Many stand characteristics used to calculate hazard may have changed since the time of the exam. If data needs to be modeled to current condition, then FVS and the associated hazard rating keyword files, should be used to model hazard to a contemporary inventory date and the assumptions and keyword files used documented in the project file. As always, it is prudent to ground check results.

Hazard Rating Maps

The integration of database and geographic information system (GIS) software enables mapping of forested areas by their insect and/or disease hazard rating. These maps of stand susceptibly enable managers to identify concentrations of high- and moderate-hazard, or determine the composition of hazard levels across a landscape.

Large, contiguous forested areas of high insect hazard promote epidemic forest insect populations by providing large areas of quality food. When high-hazard areas are small and intermixed with low-hazard areas, forest insect populations are not as likely to grow and cause significant resource impacts. Low-hazard areas have host species for a particular insect, but the host is not of high enough quality and/or in large enough quantity to allow forest insect populations to build substantially. Forest insects may still cause significant mortality in the host components of low-hazard forested areas in a landscape, but losses will be lower than in a landscape where high-hazard forested areas occur across a number of contiguous acres.

Appropriate Use of Hazard Maps

Spatial depictions of hazard are powerful tools for managers and planners at the broad- (Regional assessments), mid- (Forest assessment), and at the base- (Project assessment) levels (Nelson et al. 2015). Such maps help managers identify areas that have the highest probability of significant forest insect activity. Although hazard ratings do not predict when insects will damage resources, experience has shown that forest insects are most likely to occur where there are abundant high hazard forested areas (Williams et al. 2018). Hazard ratings address the quality and quantity of food available, but do not address insect populations. Therefore, additional information would be necessary to assess risk and predict loss.

Keep in mind the methods used to develop a hazard map. Many times the accuracy of the data is unknown. This does not mean hazard maps generated from such data are not useful, but it is necessary to acknowledge data limitations and to explain to map consumers how data quality may affect the accuracy of the hazard map. If developed correctly, using current spatial and tabular data of known accuracy, hazard maps can identify areas with the largest preponderance of stands susceptible to forest insect outbreaks. Furthermore, due to stand/polygon heterogeneity, not every tree or plot within a high hazard polygon may be susceptible to the insect pest.

Understanding relationships of dominance type, size class, and canopy cover to various forest insect hazard ratings assists with developing forest insect hazard maps. Tools have been developed by the R1 vegetation analysis team to understand the relationships of vegetation classification attributes used in R1 (Barber et al. 2010) to the resulting hazard ratings. These relationships can then be applied to existing vegetation layers such as R1-VMap, FSVeg Spatial, or a hybrid of the two. Furthermore, other spatial information such as maps designating wildlife habitat, wildland urban-interface, potential vegetation, long-term climatic trends (such as downscaled, 30-year mean drought index), treatment opportunities, etc. can be integrated when developing these coverages to provide additional hazard rating data or planning criteria.

Project Planning

A hazard map is the easiest way for managers to quickly identify areas with the highest likelihood of significant forest insect activity. However, more information will be needed to plan management activities in project areas. At the project level the assumption that stands are homogeneous is no longer appropriate.

The manager should also consider the current level of insect activity in the area. Current insect activity is the magnitude of an insect population affecting a forested area as determined by the number of currently infested trees and their proximity to the stand being assessed. Insect activity is a dynamic variable and may change quite suddenly due to factors such as adverse or favorable weather conditions, or immigration and emigration of insects. For this reason insect activity should be reviewed every year or two.

Additional information from a variety of sources, including recent walkthrough assessments, plot-level model runs (Forest Insect and Disease Tally system [FINDIT]) (Bentz 2000, McMahan et al. 2018), aerial photographs and insect aerial detection surveys should be gathered to help better characterize stand conditions and insect activity when determining which areas are most critical for treatment. Hazard ratings are provided for individual stands/ plots and do not account for the importance of the landscape scale context. Landscape-scale distributions of susceptible forest conditions can provide habitat where insect populations may amplify to levels that can overwhelm benefits from stand-level hazard reduction treatments (Schmid and Mata 2005).

Ways to Alter Hazard: Management Considerations

Hazard can be altered through silvicultural practices that break up large, homogeneous blocks of susceptible forest that can host major insect and disease populations (Williams et al. 2018). Specific silvicultural practices to reduce hazard vary with the insect involved.

By using FVS and associated keywords for hazard ratings, various silvicultural prescriptions can be evaluated. Immediate and long-term effects for various management scenarios can be compared for how they affect a given insect-cause hazard over time.

Insect Hazard Rating Systems Available to Region 1

Region 1 FHP staff formulated forest insect hazard rating systems based on research which identified site and stand characteristics associated with areas, which experienced high levels of forest pest activity. Each insect hazard rating system and a reference section of supporting literature is included in its own appendix at the end of this document.

The hazard ratings were derived specifically to be used with commonly collected tree and stand-level attributes with the fewest variables and least amount of biological complexity possible. For some insects, hazard ratings exist that incorporate additional factors (such as tree age, growth rates, or elevation) that may provide more accurate assessments. Information on these other ratings are noted in the references for each insect, and many are found in the updated FINDIT program (McMahan et al. 2018). Region 1 hazard ratings are calculated by looking at a combination of site and stand characteristics and assigning a relative index value in terms of susceptibility to the pest. By multiplying the index values, a composite index is calculated, and the composite index is assigned a hazard rating. In the subsequent rating system descriptions for the individual insects, the following formula is used.

Calculated Value = Criteria A rating * Criteria B rating * Criteria C rating

Each hazard rating system was translated into a Forest Vegetation Simulator (FVS) (Dixon 2002) event monitor keyword set which calculates hazard using the original criteria in the published hazard rating system then summarizes hazard into 1 of 4 possible classes:

- ☐ 0 = Very Low (Little to no host species but forested; possibly not forested)
- ☐ L or 1 = Low Hazard
- ☐ M or 2 = Moderate Hazard
- ☐ H or 3 = High Hazard.

See Appendix 10 for the keyword sets. These summary ratings (0, L, M, H) are displayed in FSVeg for R1 data, available in the R1 Summary Database Analysis tool, and may be output by FVS.

The hazard criteria for the following insects (**acronyms**) and host combinations are in this document:

- spruce beetle (**SB**) (*Dendroctonus rufipennis*) (Appendix 1)
- Douglas fir beetle (**DFB**) (*Dendroctonus pseudotsugae*) (Appendix 2)
- mountain pine beetle (**DFB**) (*Dendroctonus ponderosae*) and western pine beetle (**WPB**) (*Dendroctonus brevicomis*) in ponderosa pine (Appendix 3)
- mountain pine beetle (**MBP**) (*Dendroctonus ponderosae*) in western white pine (Appendix 4)
- mountain pine beetle (**MBP**) (*Dendroctonus ponderosae*) in lodgepole pine (Appendix 5)
- mountain pine beetle (**MPB**) (*Dendroctonus ponderosae*) in whitebark pine/ limber pine (Appendix 6)
- pine bark beetle (**MPB** and **Ips** spp.) (*Dendroctonus* and *Ips* species) in combined host (Appendix 7)
- western spruce budworm (**WSBW**) (*Choristoneura occidentalis*) and Douglas-fir tussock moth (**DFTM**) (*Orygia pseudotsugae*) in Douglas fir and true firs (Appendix 8)

Please note **QMD** = quadratic mean diameter, **BA** = basal area, **DBH** = diameter breast height. All metrics are in English units.

Conclusion

The use of landscape hazard rating maps for forest insects will assist managers in determining the potential for these disturbance agents to interfere with a manager's ability to reach established objectives. By identifying areas in the landscape with a preponderance of high hazard conditions prior to insect outbreaks, managers have an opportunity to reduce hazard through silvicultural prescriptions, or to determine if action is warranted. Tools which look at hazard, from landscape (broad- mid- or base-level) hazard maps to an individual stand's hazard rating (Nelson et al. 2015), allow managers to proactively promote insect resistance by altering hazard conditions instead of reacting to insect activity.

References

Barber, J., Berglund, D., Bush, R. 2010. The Region 1 existing vegetation classification system and its relationship to inventory data and the Region 1 existing vegetation map products. Vegetation, Classification, Inventory, and Analysis Report # 10-08 6.0. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 30 p.

Bentz, B. 2000. Forest Insect and Disease Tally System (FINDIT) user manual. Gen. Tech. Rep. RMRS-GTR-49. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Dixon, G. 2002 (revised 2013). Essential FVS: A user's guide to the Forest Vegetation Simulator. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center. 244 p.

McMahan, A.J., Steed, B.E., Lowrey, L., Zweifler, M.O. 2018. FINDIT macro-enabled Excel calculator V2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team (FHTET).

Nelson, M., Brewer, K., Solem, S. 2015. Existing vegetation classification, mapping, and inventory technical guide version 2.0. Gen. Tech. Report WO-90. Washington, DC: U.S. Department of Agriculture, Forest Service, Ecosystem Management Coordination Staff. 210 p.

Randall, C., Bush, R. 2010. R1 forest insect hazard rating system user guide for use with inventory data stored in FSVeg and/or Veg Simulator. FHP Report 10-05. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 26 p.

Randall, C., Steed, B., Bush, R. 2011. Revised R1 forest insect hazard rating system user guide for use with inventory data stored in FSVeg and/or Veg Simulator. FHP Report 11-06. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 27 p.

Schmid, J.M., Mata, S.A. 2005. Mountain pine beetle–caused tree mortality in partially cut plots surrounded by unmanaged stands. RP–RM–54. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 11 p.

Williams, H., Hood, S., Keyes, C., Egan, J., Negron, J. 2018. Subwatershed-level lodgepole pine attributes associated with a mountain pine beetle outbreak. Forests, 9:1-17.

CITATION FOR THIS REPORT:

Randall, C., Steed, B., Egan, J. Bush, R. and N. Morgan. 2018. 2018 Revised R1 Forest Insect Hazard Rating System User Guide for use with Inventory Data Stored in FSVeg and/or Analyzed with the Forest Vegetation Simulator (FVS). FHP Report 18-08. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 31 p.

APPENDIX 1: SPRUCE BEETLE

Spruce beetle (SB) outbreaks cause extensive tree mortality and modify stand structure by reducing the average spruce tree diameter, height, and stand density. Residual trees are often slow-growing small and intermediate sized trees, which eventually become dominant. In the Rocky Mountain West, Engelmann spruce is the species most often impacted.

Stand Conditions Conducive To Infestations

Endemic SB populations usually live in wind-thrown trees. When populations increase to high levels in downed trees, beetles may attack susceptible, large diameter standing trees. Most outbreaks originate in wind-thrown trees. Once beetle populations reach high levels, more relatively healthy trees are attacked.

In mature stands, larger diameter (≥18inches DBH) trees usually are attacked first. If an infestation persists in a stand, smaller diameter trees may be attacked.

In the Rocky Mountain area, susceptibility of a stand to SB attack is based on the physiographic location, tree diameter, BA, and percentage of Engelmann spruce in the overstory. Engelmann spruce stands are highly susceptible if they grow on well-drained sites in creek bottoms, have an average DBH of 16 inches or more, have a BA greater than 150 square feet per acre, and have more than 65 percent spruce in the overstory. Since stand physiographic location is not captured in inventory data, it was omitted in the hazard calculation but could be added when evaluating specific stands within a project-area or generating a hazard map.

Interpreting Hazard

High hazard stands are those in which large amounts of spruce mortality can be expected once a SB outbreak occurs. Moderate and low hazard stands may experience less beetle-caused mortality; but individual large, old spruce might still be killed. When high-hazard stands are intermixed with low-hazard stands, beetle populations may not be as active. Low hazard stands may have spruce, but are either not of high enough quality or in large enough quantity to allow SB populations to remain at high levels. SB may still cause significant mortality in the spruce component of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

Hazard Criteria for Spruce Beetle[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	QMD of Engelmann spruce ≥10" DBH	<12"	12"≤ QMD < 16"	≥16"
B	BA for all species	<100 ft^2/ac	100 ≤ BA < 150 ft^2/ac	≥150 ft^2/ac
C	% of total BA that is Engelmann spruce ≥10" DBH	<50%	50% ≤ % BA < 65%	≥65%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

References

Holsten, E.H., Their, R.W., Munson, A. S., Gibson, K.E. 1999. The spruce beetle. Forest Insect and Disease Leaflet 127. Washington, DC: U.S. Department of Agriculture, Forest Service. 12 p.

Munson, S. 2000. Personal communication. USDA Forest Service, Forest Health Protection Group Leader, Ogden Field Office, Ogden, UT.

Schmid, J.M., Frye, R.H. 1976. Stand ratings for spruce beetles. Res. Note RM309. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

APPENDIX 2: DOUGLAS-FIR BEETLE

Douglas-fir beetles (DFB) normally kill small groups of Douglas-fir trees, but during outbreaks mortality of up to 100 trees are not uncommon. Outbreaks last in duration from two to four years. Those of longest duration coincide with periods of drought.

Stand Conditions Conducive To Infestations

At low or endemic levels, the DFB infests scattered trees, including windfalls and trees injured by fire scorch, defoliation, or root disease. Where such susceptible trees are abundant, once they have been infested and killed, beetle populations can build up rapidly and spread to adjacent green, standing trees. Damage is greatest in dense stands of mature Douglas-fir. Various fungi introduced by the DFB also contribute to mortality of infested trees.

Interpreting Hazard

High-hazard stands are those in which large amounts of Douglas-fir mortality is expected once a DFB outbreak occurs. Moderate- and low-hazard stands may experience less beetle-caused mortality, but individual large, old Douglas-fir trees might still be killed.

When high-hazard stands are intermixed with low-hazard stands, DFB populations may not be as active. Low hazard stands may have Douglas-fir, but either not of high enough quality or in large enough quantity to allow DFB populations to remain at high levels. DFB may still cause significant mortality in the Douglas-fir components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

The likelihood of a DFB infestation developing within a stand is related to the proportion of susceptible Douglas-fir and overall stand density. Generally, DFB attacks are most successful on Douglas-fir trees that are mature or over-mature, large in diameter, and are growing in more densely stocked stands. A very high stand density may increase the susceptibility of younger and smaller diameter Douglas-fir trees. The higher the proportion of trees with susceptible characteristics, the higher the susceptibility of the stand to DFB attack.

Hazard Criteria for Douglas-fir Beetle[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	QMD for Douglas-fir $\geq$ 9" DBH	<10"	10" $\leq$ QMD < 14"	$\geq$14"
B	BA for all species	<100 ft^2/acre	100 $\leq$ BA < 250 ft^2/acre	$\geq$250 ft^2/acre
C	% of total BA that is Douglas-fir $\geq$9" DBH	<50%		$\geq$50%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	$\geq$18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

References

Forest Service. 1999. Douglas-fir beetle in the Intermountain West. Forest Health Protection Leaflet R1-04-78. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain and Northern Regions

Furniss, M.M., Livingston, R.L., McGregor, M.D. 1981. Development of a stand susceptibility classification for Douglas-fir beetle. In: Hedden, R.L., Barras, S.J., J.E. Coster, tech. coords. Hazard-rating systems in

forest insect pest management. Gen. Tech. Rep. WO-27. Washington D. C.: U.S. Department of Agriculture, Forest Service: 115-128

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest Health Protection Report 00-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 39-42 p.

Randall, C., Tensmeyer, G. 1999. Douglas fir beetle hazard rating system using the Oracle database and the Forest Service IBM platform. Forest Health Protection Report 99-6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 5 p.

Schmitz, R.E., Gibson, K.E. 1996. Douglas-fir beetle. Forest Insect and Disease Leaflet 5. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

Weatherby, J.C., Their, R.W. 1992. A preliminary validation of a Douglas-fir beetle hazard rating system, Mountain Home Ranger District, Boise National Forest. Forest Pest Management Report R4-93-05. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region.

APPENDIX 3: MOUNTAIN PINE BEETLE /WESTERN PINE BEETLE / PINE ENGRAVERS IN PONDEROSA PINE

Ponderosa pine is susceptible to a number of tree killing bark beetles including mountain pine beetle (MPB) and western pine beetle (WPB). Although MPB and WPB are the beetle species most likely to impact mature stands of ponderosa pine, several pine engravers (*Ips pini* and other *Ips* species) may associate with these primary species in a bark beetle complex.

Stand Conditions Conducive to Infestations

Bark beetles respond to stressed ponderosa pine. Stands most susceptible to bark beetle attacks have a high composition of susceptible host or dense stands comprised of large diameter ponderosa pine. There are some subtle differences in ponderosa pine stands susceptible to MPB and those susceptible to WPB, but for the purpose of analysis, we have combined these beetles in the hazard rating criteria.

Interpreting Hazard

Hazard is defined by two factors, the quality and the quantity of susceptible ponderosa pine. The quality of the ponderosa pine component of a stand as a MPB or WPB food source is best characterized by stand density and phloem thickness. Since ponderosa pine phloem thickness is not generally measured in most inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked ponderosa pine stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand.

When high-hazard stands are surrounded by low-hazard stands, beetle populations may not be as significant. Low-hazard stands may have ponderosa pine, but are either not of high enough quality or in large enough quantity to allow beetle populations to remain at high levels. Beetles may still cause significant mortality in the ponderosa pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high hazard stands are clustered.

Hazard Rating Criteria for Bark Beetles in Ponderosa Pine[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	QMD of ponderosa pine≥5" DBH	<6"	6" ≤ QMD < 10"	≥10"
B	BA all species ft²/acre	<80 ft²/acre	80 ≤ BA< 120 ft²/acre	≥120 ft²/acre
C	% of total BA that is ponderosa pine ≥5" DBH	<40%	40% ≤ % BA< 65%	≥65%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft² BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

References

Chojnacky, D.C., Bentz, B.J., Logan, J.A. 2000. Mountain pine beetle attack in ponderosa pine: Comparing methods for rating susceptibility. Res. Paper RM-RP-26. Logan, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest Health Protection Report 00-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 39-42 p.

Randall, C., Bush, R., Wolf, A. 2011. Analysis of the impacts of mountain pine beetle on lodgepole and ponderosa pine in Warm Springs Analysis Area, Helena National Forest 2006-2008. Inventory and Analysis Report 11-09 v1.1. Missoula, MT: U.S. Department of Agriculture, Forest Service, Forest Health Protection. 24p.

Schmid, J.M., Mata, S.A., Obedzinski, R.A. 1994. Hazard rating ponderosa pine stands for mountain pine beetles in the Black Hills. Res. Note RM-RN-529. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

APPENDIX 4: MOUNTAIN PINE BEETLE IN WESTERN WHITE PINE

Until about 75 years ago western white pine was the most abundant forest type in the Northern Rocky Mountain province. The causes of change include mountain pine beetle (MPB), fire suppression, and past harvesting. The primary agent of change, however, is white pine blister rust (*Cronartium ribicola*). White pine blister rust continues to kill most white pine trees that regenerate naturally and white pine blister rust and bark beetles continue to kill remaining large trees. Maintaining stands of white pine that remain is a high priority.

Stand Conditions Conducive To Infestations

Based on historical accounts of past MPB outbreaks, we know that dense stands (greater than 140 square feet per acre BA) with a large component (> 60 percent stand BA) of large diameter (QMD >8inch DBH) white pine trees sustain the greatest losses to MPB.

Interpreting Hazard

High hazard is defined by two factors, the quality and the quantity of susceptible western white pine. The quality of the western white pine component of a stand as a MPB food source is best characterized by stand density and phloem thickness. Since western white pine phloem thickness is not generally measured in inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked western white pine stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand.

When high-hazard stands are intermixed with low-hazard stands, MPB populations may not be as significant. Low-hazard stands may have western white pine, but are either not of high enough quality or in large enough quantity to allow beetle populations to remain at high levels. MPB may still cause significant mortality in the western white pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

Hazard Criteria for Mountain Pine Beetle in Western White Pine[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High (3)
A	QMD white pine ≥5" DBH	<8"	8" ≤ QMD < 12"	≥12"
B	BA all species (ft^2/acre)	<80 ft^2/acre	80 ≤ BA < 120 ft^2/acre	≥120 ft^2/acre
C	% of total BA that is white pine ≥5" DBH	<25%	25% ≤ % BA < 50%	≥50%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

Reference

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest Health Protection Report 00-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 39-42 p.

APPENDIX 5: MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

Mountain pine beetle (MPB) attacks and kills lodgepole pine. Epidemics frequently develop in lodgepole pine stands that contain well-distributed, large- diameter trees. When outbreaks are extensive, millions of trees may be killed each year. During epidemics, widespread tree mortality can alter the forest ecosystem.

Stand Conditions Conducive To Infestations

Susceptible lodgepole pine stands are dense (≥100 square feet per acre BA) and have a large component (≥50 percent BA) of large diameter (QMD ≥8 inches DBH) lodgepole pine. Outbreaks may be limited if stand BA is high enough to effectively limit individual tree diameter and phloem thickness to levels that prevent successful MPB reproduction (Safranyik and Carroll 2006).

In the original hazard rating system, stand elevation and trees per acre were also incorporated into the hazard rating calculation. After careful analysis of resulting hazard ratings, we determined that the model for MPB in lodgepole pine provided more consistent and appropriate results if the previous criteria for trees per acre 3 inches DBH or larger (Randall et al. 2010) was dropped. Elevation was also eliminated as a warming climate is expected to alter elevation thresholds.

Interpreting Hazard

Hazard is defined by two factors, the quality and the quantity of susceptible lodgepole pine. The quality of the lodgepole component of a stand as a MPB food source is best characterized by stand density and phloem thickness. Since lodgepole pine phloem thickness is not generally measured in inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the stand. A pure, well stocked lodgepole stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand. The location of a stand also has a bearing on MPB success.

When high-hazard stands are intermixed with low-hazard stands, MPB populations may not be as active. Low-hazard stands may have lodgepole pine, but are either not of high enough quality or in large enough quantity to allow beetle populations to remain at high levels. MPB may still cause significant mortality in the lodgepole pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

Hazard Criteria for Mountain Pine Beetle in Lodgepole Pine[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	QMD of lodgepole pine ≥5" DBH	<7"	7" ≤ QMD < 8"	≥8"
B	BA all species (ft^2/acre)	<80 or ≥250 ft^2/acre	80 ≤ BA < 120 ft^2/acre	120 ≤ BA < 250 ft^2/acre
C	% of total BA that is lodgepole pine ≥5" DBH	<25%	25% ≤ % BA < 50%	≥50%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

References

Amman, G.D. 1977. The role of the mountain pine beetle in lodgepole pine ecosystems: impact on succession. In: Mattson, W.J., ed. Arthropods in forest ecosystems. Proceedings in the Life Sciences. New York: Springer-Verlag. Amman, G.D., McGregor, M. D., Dolph, Jr., R.E. 1990. The mountain pine beetle. Forest Insect and Disease Leaflet 2. Washington, DC: U.S. Department of Agriculture, Forest Service. 12 p.

Bell-Randall, C., Tensmeyer, G. 2000. Hazard rating system for mountain pine beetle in lodgepole pine using the Oracle database and the Forest Service IBM platform. Forest Health Protection Report 00-6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 5 p.

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest Health Protection Report 00-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 39-42 p.

Safranyik L, Carroll A. 2006. The biology and epidemiology of the mountain pine beetle in lodgepole pine forests. In: Safranyik L, Wilson W (eds) The mountain pine beetle: a synthesis of biology, management, and impacts on lodgepole pine. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C., Canada, pp 3–66.

Shore, T., Safranyik, L. 1992. Susceptibility and risk rating system for the mountain pine beetle in lodgepole pine stands. Information Report BC-X-336. Victoria, BC: Forestry Canada, Pacific Forestry Centre. 12 p.

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

Appendix 6: Mountain Pine Beetle in Whitebark Pine/ Limber Pine

The high elevation five-needle pines, as a group, provide essential habitat for wildlife, often being the major source of cover in high elevation environments. The range of limber pine partially overlaps with that of whitebark pine. Most recent work on mountain pine beetle (MPB) in high elevation pines has been centered on whitebark pine; however, much of the information appears to apply to limber pine as well.

Stand Conditions Conducive To Infestations

Historically, the principal natural mortality agent of whitebark pine was the MPB. Perkins (2003) found tree and stand-level characteristics associated with MPB attack in whitebark pine are qualitatively similar to other MPB–pine host systems, although the attack thresholds are quantitatively different. Whitebark pine stands with BAs below 44 square feet per acre and trees with QMD below 7 inches were not attacked in the early 20th century epidemic in central Idaho. These factors, and other MPB hazard information, were used to build the whitebark/limber pine hazard criteria for MPB.

Interpreting Hazard

Hazard is defined by two factors, the quality and the quantity of susceptible whitebark and limber pine. The quality of the pine component as a MPB food source is best characterized by stand density and phloem thickness. Since phloem thickness is not generally measured in inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked pine stand will be more likely to support a large MPB population than a mixed species and/or poorly stocked stand.

When high-hazard stands are intermixed with low-hazard stands, beetle populations may not be as active. Low-hazard stands may have whitebark and limber pine, but are either not of high enough quality or in large enough quantity to allow beetle populations to remain at high levels. MPB may still cause significant mortality in the whitebark and limber pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

Hazard Criteria for Mountain Pine Beetle in Whitebark and Limber Pines[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High (3)
A	QMD of whitebark and limber pine ≥5" DBH	<7"	7" ≤ QMD < 12"	≥12"
B	BA all species (ft^2/acre)	<40 ft^2/acre	40 ≤ BA < and 45 ft^2/acre	≥45 ft^2/acre
C	% of total BA that is whitebark and limber pine ≥5" DBH	<25%	25% ≤ % BA < 50%	≥50%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9)

References

Arno, S.F. 1986. Whitebark pine cone crops—a diminishing source of wildlife food? Western Journal of Applied Forestry 1: 92–94.

Arno, S.F., Hoff, R.J. 1989. Silvics of whitebark pine (*Pinus albicaulis*). Gen. Tech. Rep. INT- GTR-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. p. 11.

Bartos, D.L., Gibson, K.E. 1990. Insects of whitebark pine with emphasis on mountain pine beetle. In: Schmidt, W., McDonald, K., comps. Whitebark pine ecosystems: ecology and management of a high mountain resource: Proceedings of a symposium. Gen. Tech. Rep. INT-GTR-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 171-178.

Ciesla, W.M., Furniss, M.M. 1975. Idaho's haunted forests. American Forests 81: 32–35..

Kegley, S. 2008. Personal Communication. USDA Forest Service, Forest Health Protection Entomologist, Coeur d'Alene Field Office, Coeur d'Alene, ID.

Kendall, K.C. 1997. Limber Pine Communities. http://www.nrmsc.usgs.gov/research/limber.h tm.

Perkins, D.L., Roberts, D.W. 2003. Predictive models of whitebark pine mortality from mountain pine beetle. Forest Ecology and Management 174: 495-510.

Perkins, D.L., Swetnam, T.W. 1996. A dendroecological assessment of whitebark pine in the Sawtooth-Salmon River region Idaho. Canadian Journal of Forest Research 26: 2123–2133.

APPENDIX 7: PINE BEETLE IN COMBINED PINE HOST

A number of bark beetles, including MPB (*Dendroctonus ponderosae*), pine engraver beetles (*Ips* species), and western pine beetle (*Dendroctonus brevicomis*), attack and kill pines (*Pinus* species). Hazard rating systems have been developed for individual host species; however these systems are not able to accurately assess the hazard of stands containing multiple pine species. It is necessary to group individual pine species components in order to accurately assess hazard.

We developed this hazard rating system by integrating the logic for the individual host species hazard rating systems presented in this document.

Stand Conditions Conducive To Infestations

Susceptible mixed pine stands are dense and have a large combined pine species component of trees greater than 6 inches DBH. This size threshold is based on an averaging of the various individual MPB hazard ratings. Most of these individual species ratings have similar thresholds for the hazard criteria. Because MPB in Region 1 is largely driven by lodgepole pine, the averaging weighted heavily to thresholds in the lodgepole pine hazard rating. In addition, stands where several pine species co-occur, lodgepole is often one of the species present.

Hazard Criteria for Mountain Pine Beetle in All Pines Combined[1]

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	QMD whitebark ≥5" DBH or QMD limber ≥ 5"DBH OR QMD western white ≥5" DBH or QMD lodgepole ≥5"DBH OR QMD ponderosa pine ≥5" DBH Start with high- if none of the species meet high, then go to moderate and then to low. Just one of the species needs to meet the criteria to get the higher rating.	<6"	6" ≤ QMD < 8"	≥8"
B	BA all species (ft^2/acre)	<80 ft^2/acre	80 ≤ BA < 120 ft^2/acre	120 ≤ BA
C	% of total pine BA ≥5" DBH	<25%	25% ≤ % BA < 50%	≥50%

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate [1]	2-17	2, M
High [1]	≥18	3, H

[1]For stands/plots with < 40 ft^2 BA, hazard is rated as 'Low' due to reduced bark beetle habitat suitability at low stand densities (Appendix 9**)**

Interpreting Hazard

Hazard is defined by two factors, the quality and the quantity of susceptible pine. The quality of the pine component of a stand as a MPB food source is best characterized by stand density and phloem thickness. Since phloem thickness is not generally measured in inventories, DBH and other available stand characteristics are used as surrogates. The quantity of the food source refers to the species composition and density of the forest. A pure, well stocked pine species stand will be more likely to support a large MPB population than a mixed host and non-host species and/or poorly stocked stand. The location of a stand also has a bearing on MPB success.

When high-hazard stands are intermixed with low-hazard stands, beetle populations may not be as active. Low-hazard stands may have pine components, but are either not of high enough quality or in large enough quantity to

allow beetle populations to remain at high levels. MPB may still cause significant mortality in the pine components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands are clustered.

References

Amman, G.D. 1977. The role of the mountain pine beetle in lodgepole pine ecosystems: impact on succession. In: Mattson, W.J., ed. Arthropods in forest ecosystems. Proceedings in the Life Sciences. New York: Springer-Verlag.

Amman, G.D., McGregor, M. D., Dolph, Jr., R.E. 1990. The mountain pine beetle. Forest Insect and Disease Leaflet 2. Washington, DC: U.S. Department of Agriculture, Forest Service. 12 p.

Arno, S.F. 1986. Whitebark pine cone crops—a diminishing source of wildlife food? Western Journal of Applied Forestry 1: 92–94.

Arno, S.F., Hoff, R.J. 1989. Silvics of whitebark pine (*Pinus albicaulis*). Gen. Tech. Rep. INT- GTR-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. p. 11.

Bartos, D.L., Gibson, K.E. 1990. Insects of whitebark pine with emphasis on mountain pine beetle. In: Schmidt, W., McDonald, K., comps. Whitebark pine ecosystems: ecology and management of a high mountain resource: Proceedings of a symposium. Gen. Tech. Rep. INT-GTR-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 171-178.

Bell-Randall, C., Tensmeyer, G. 2000. Hazard rating system for mountain pine beetle in lodgepole pine using the Oracle database and the Forest Service IBM platform. Forest Health Protection Report 00-6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 5 p.

Chojnacky, D.C., Bentz, B.J., Logan, J.A. 2000. Mountain pine beetle attack in ponderosa pine: Comparing methods for rating susceptibility. Res. Paper RM-RP-26. Logan, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.

Ciesla, W.M., Furniss, M.M. 1975. Idaho's haunted forests. American Forests 81: 32–35.

Hagle, S., Johnson, T., Stipe, L., Schwandt, J., Byler, J., Kegley, S., Bell Randall, C., Taylor, J., Lockman, B., Sturdevant N. 2000. Successional functions of pathogens and insects; ecoregion sections M332a and M333d in northern Idaho and western Montana. Volume 1: Methods. Forest Health Protection Report 00-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 39-42 p.

Kegley, S. 2008. Personal Communication. USDA Forest Service, Forest Health Protection Entomologist, Coeur d'Alene Field Office, Coeur d'Alene, ID.

Kendall, K.C. 1997. Limber Pine Communities. http://www.nrmsc.usgs.gov/research/limber.h tm.

Perkins, D.L., Roberts, D.W. 2003. Predictive models of whitebark pine mortality from mountain pine beetle. Forest Ecology and Management 174: 495-510.

Perkins, D.L., Swetnam, T.W. 1996. A dendroecological assessment of whitebark pine in the Sawtooth-Salmon River region Idaho. Canadian Journal of Forest Research 26: 2123–2133.

Schmid, J.M., Mata, S.A., Obedzinski, R.A. 1994. Hazard rating ponderosa pine stands for mountain pine beetles in the Black Hills. Res. Note RM-RN-529. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

Shore, T., Safranyik, L. 1992. Susceptibility and risk rating system for the mountain pine beetle in lodgepole pine stands. Information Report BC-X-336. Victoria, BC: Forestry Canada, Pacific Forestry Centre. 12 p.

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

Appendix 8: Western Spruce Budworm/Douglas-fir Tussock Moth

Western spruce budworm (WSBW) and Douglas-fir tussock moth (DFTM) are defoliating insects, which eat the needles of Douglas-fir and true fir trees, though other species may be defoliated during epidemics. When populations of these insects reach epidemic proportions, they can cause a reduction in growth, top kill, tree mortality, and mortality of regenerating trees. WSBW outbreaks tend to last longer and cause less direct tree mortality because budworms preferentially feed on current year foliage. DFTM outbreaks tend to be shorter in duration (2-3 years), but result in more significant mortality losses because tussock moth larvae may completely defoliate a tree.

This hazard rating system is based on the presence and density of species known to be susceptible to defoliators in the Northern Region. This represents a very coarse assessment of variables commonly available within inventory data and does not depict other critical factors related to defoliation including the presence of multiple canopy layers or the relative susceptibility of true fir, Douglas-fir, and spruce hosts. Forest Health Protection recommends limited-use of these ratings. They may be beneficial as a starting point for assessment, but further site-specific forest composition and structure information is needed to accurately represent susceptibility to defoliators.

Stand Conditions Conducive To Infestations

Because larvae of both species disperse by moving up and out from their egg masses and spinning silken thread to balloon on the wind to a new host, they tend to be more destructive in dense (high BA) stands with a high host (Douglas-fir/true fir) component and multiple canopy layers which intercept ballooning larvae.

Interpreting Hazard

High-hazard stands are those in which a large amount of Douglas-fir and true fir defoliation is expected once an outbreak of WSBW or DFTM occurs. Moderate- and low-hazard stands may experience less defoliation and defoliator-caused growth loss, top kill, or mortality.

When high-hazard stands are intermixed with low-hazard stands, defoliator populations may not be as active. Low-hazard stands may have host species, but are either not of high enough quality or in large enough quantity to allow defoliator populations to remain at high levels. Defoliators may still cause significant mortality in the host components of low hazard stands in a landscape, but losses will be lower than in a landscape where high hazard stands are clustered.

Hazard Criteria for Western Spruce Budworm/Douglas-fir Tussock Moth

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	BA all species (ft^2/acre)	<80 ft^2/acre	80 ≤ BA < 100 ft^2/acre	≥100 ft^2/acre
B	% of total BA that is: Engelmann spruce, subalpine fir, grand fir, and Douglas-fir ≥5" DBH	<50%	50% ≤ % BA < 80%	≥80%
C	Trees per acre ≥5" DBH	<50 /acre	50 ≤ TPA < 100 /acre	≥100 /acre

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate	2-17	2, M
High	≥18	3, H

References

Steele, R., Williams, R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., Their, R.W. 1996. Standard hazard rating for central Idaho forests. Gen. Tech. Rep. INT-GTR-332. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 18 p.

Stoszek, K.J., Mika, P.G. 1985. Rating stand hazard to western spruce budworm: ground survey models. In: Brooks, M.H.; Colbert, J.J.; Mitchell R.G.; Stark, R.W., tech. coords. Managing trees and stands susceptible to western spruce budworm. Tech. Bull. 1695. Washington, DC: U.S. Department of Agriculture, Forest Service: 48-50.

Stoszek, K.J., Mika, P.G., Moore, J.A., Osbourne, H.L. 1981. Relationship of Douglas-fir tussock moth defoliation to site and stand characteristics in northern Idaho. Forest Science 27: 431-442.

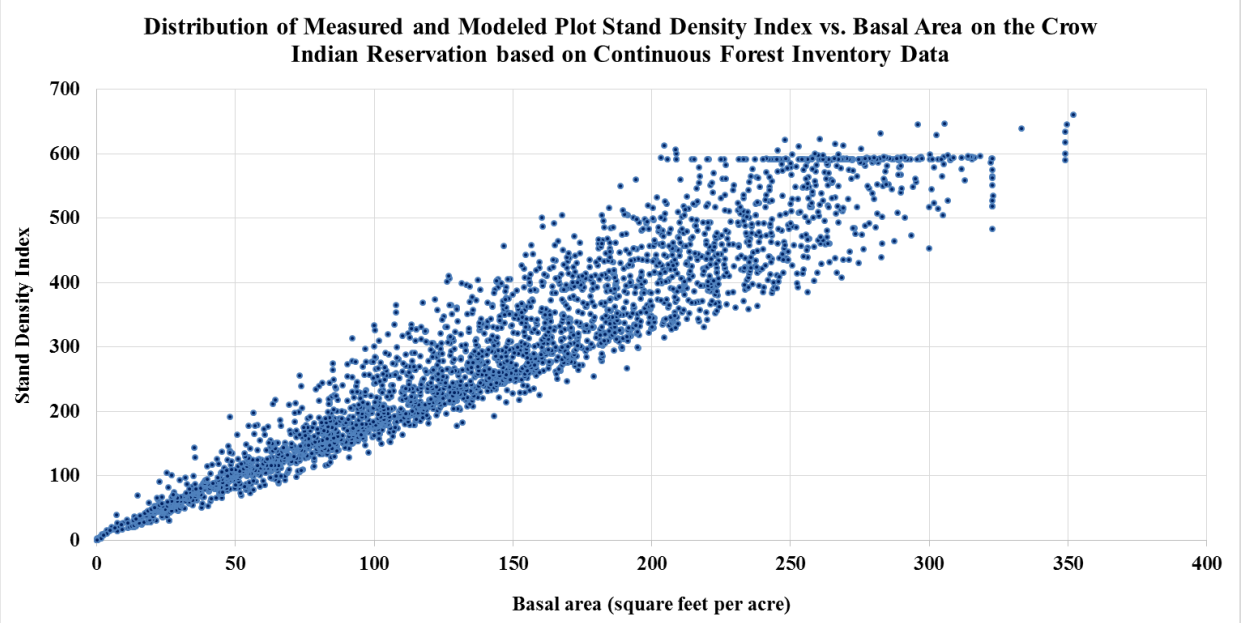
Weatherby, J.C., Gardner, B.R., Barbouletos, T.N. 1993. A Douglas-fir tussock moth hazard rating system for use in southern Idaho. Forest Pest Management Report R4-93-04. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 14 p.

APPENDIX 9: BASIS FOR 40 SQUARE FOOT BASAL AREA THRESHOLD APPLIED TO BARK BEETLE HAZARD RATINGS.

Data were reviewed from *n* = 2,987 measured and FVS-modeled inventory plots dominated by ponderosa pines, lodgepole pines, or Douglas-fir species compositions (Egan and Hayes 2015). For these plots, the relationship between basal area ranges associated with stand density index (SDI) values were examined to derive a threshold a 'Low' susceptibility state for ponderosa pines. Low susceptibility was identified at density levels < 150 SDI across 662 plots that were exposed to bark beetle population pressure and documented across 17 western yellow pine research studies (Egan et al. 2018, unpublished data).

It was assumed lodgepole pine forests have similar low-density resistance based on microclimate factors. This assumption is supported by multiple studies (such as Whitehead et al. 2007) cited within Egan et al. (2014) white paper summarizing mountain pine beetle treatment effectiveness. Similarly, this threshold was extrapolated to Douglas-fir beetle and spruce beetle based on best-available science and FHP specialist expert opinion (Schmid and Frye 1976, Negron et al. 1999).

From this analysis, we derived the threshold where anything < 40 square feet per acre of basal area, and considered forested, is automatically attributed with a 'Low' susceptibility rating. An alternate threshold of <= 50 square feet of basal area per acre was considered, but was not advised, because as SDI levels approached 200 trees would be moderately susceptible to beetle-attack based on Egan et al. (2018).



, b

References

Egan, J., Kegley, S., Blackford, D., Jorgensen, C. 2014. Effectiveness of direct and indirect mountain pine beetle control treatments as implemented by the USDA Forest Service. Numbered Report 14-03. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 13 p.

Egan, J., Hayes, C. 2015. Analysis of stand susceptibility with continuous forest inventory plots in the Pryor and Wolf Mountains, Crow Indian Reservation. Numbered Report 15-05. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 15 p.

Egan et al. 2018, unpublished data. Meta-analysis of *Dendroctonus* spp. resistance across western U.S. yellow pine forests. *Manuscript in preparation as of 10/5/18. Data available upon request.*

Negron, J.F., W.C. Schaupp, Jr., K.E. Gibson, J. Anhold, D. Hansen, R. Thier, and P. Mocettini. 1999. Estimating extent of mortality associated with the Douglas-fir beetle in the central and northern Rockies. W.J. App. For. Vol. 14, No. 3, p. 121-127.

Schmid, J.M., Frye, R.H. 1976. Stand ratings for spruce beetles. Res. Note RM309. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p.

APPENDIX 10: INSECT_HAZARD_RATING .KCP FILES

Forest Vegetation Simulator keyword files which assign hazard ratings for forest insects to settings in the R1 Summary Database Analysis tool. There are two .kcp files, A) the Inland Empire, North Idaho & KooKanTL variants and B) the Eastern Montana variant. The below keyword files are included in the zip file folder with this publication.

A) Inland Empire, North Idaho & KooKanTL variants **********

```
COMMENT
Computes pest hazard ratings.
IE_Insect_Hazard_rating.kcp  - Forest Health Hazard Rating System   11/23/2018
For IE variant, Uses alpha species codes
R1 FHM Staff, derived these hazard ratings based on citations listed in
FHP Report "2018 Revised R1 Forest Insect Hazard Rating System User Guide for use
with
Inventory Data Stored in FSVeg and/or Analyzed with the Forest Vegetation Simulator"
Dec. 2018

Updates 07/05/2018 - For all moderate and high bark beetle ratings if total stand
basal area < 40 ft2
rating is low (1), if total stand BA is GE 40 ft2, rating is unchanged from above
calculation 2/27/2017
Compute variables _ESBTL, _DFBTL, _PPBTL, _WPBTL, _WBBTL, _LPBTL, & _CBBTL are
ratings prior to the 40 ft2
total stand basal area criteria being applied. Final ratings are displayed as ESBTL,
DFBTL, PPBTL, WPBTL, WBBTL, LPBTL & CBBTL.

COMPUTE keyword has a “0" in the first field indicating that the ratings will be
calculated every cycle.
End

COMPUTE           0

*ESBtl=Spruce Beetle
_ESBtl=(LinInt( &
LinInt(SpMcDBH(5,ES,0,10,99,0,250,0),0,12,12,16,16,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,100,100,150,150,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,ES,0,10,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,65,65,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,ES,0,0,99,0,250,0)+0.9),1)

*DFBtl=Douglas-fir Beetle
_DFBtl=(LinInt( &
LinInt(SpMcDBH(5,DF,0,9,99,0,250,0),0,10,10,14,14,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,100,100,250,250,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,DF,0,9,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,999,.5,.5,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,DF,0,0,99,0,250,0)+0.9),1)

*PPBtl=Ponderosa Pine (MPB/WPB)
```

```
_PPBtl=(LinInt( &
LinInt(SpMcDBH(5,PP,0,5,99,0,250,0),0,6,6,10,10,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,80,80,120,120,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,PP,0,5,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,40,40,65,65,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,PP,0,0,99,0,250,0)+0.9),1)

*WPBtl=White Pine (MPB)
_WPBtl=(LinInt( &
LinInt(SpMcDBH(5,WP,0,5,99,0,250,0),0,8,8,12,12,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,80,80,120,120,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,WP,0,5,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,25,25,50,50,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,WP,0,0,99,0,250,0)+0.9),1)

*WBBtl=Whitebark Pine/Limber Pine (MPB)
_WBBtl=LinInt(LinInt(13.54*SQRT((SPMCDBH(2,WB,0,5,99)+SPMCDBH(2,LM,0,5,99))/ &
Max((SPMCDBH(1,WB,0,5,99)+SPMCDBH(1,LM,0,5,99)),1)),0,7,7,12,12,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,40,40,45,45,999,.5,.5,2,2,3,3)* &
LinInt(((SpMcDBH(2,WB,0,5,99,0,250,0)+ SpMcDBH(2,LM,0,5,99,0,250,0))/ &
Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1)*100),0,25,25,50,50,999,.5,.5,2,2,3,3) &
,0,2,2,18,18,99,1,1,2,2,3,3) * &
Min(Int(SpMcDBH(1,WB,0,0,99,0,250,0)+SpMcDBH(1,LM,0,0,99,0,250,0)+0.9),1)

*LPBtl=Lodgepole Pine 5/2011 (MPB)
_LPBtl=(LinInt( &
LinInt(SpMcDBH(5,LP,0,5,99,0,250,0),0,7,7,8,8,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),00,80,80,120,120,250,250,999, &
      .5,.5, 2,  2,  3,  3, .5, .5)* &
LinInt((SpMcDBH(2,LP,0,5,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,25,25,50,50,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,LP,0,0,99,0,250,0)+0.9),1)

*CBBtl=ComboMAX (MPB)
BA_SP =
SPMCDBH(2,WB,0,5,99)+SPMCDBH(2,LM,0,5,99)+SPMCDBH(2,WP,0,5,99)+SPMCDBH(2,LP,0,5,99)+
SPMCDBH(2,PP,0,5,99)
BA_ALL = SpMcDBH(2,All,0,.1,99,4.5,250,0)
TPA_SP =
SpMcDBH(1,WB,0,0,99)+SpMcDBH(1,LM,0,0,99)+SpMcDBH(1,WP,0,0,99)+SpMcDBH(1,LP,0,0,99)+
SpMcDBH(1,PP,0,0,99)
QMD_SP =
Max(SPMCDBH(5,WB,0,5,99),SPMCDBH(5,LM,0,5,99),SPMCDBH(5,WP,0,5,99),SPMCDBH(5,LP,0,5,
99),SPMCDBH(5,PP,0,5,99),1)

_CBBtl=LinInt &
(LinInt(QMD_SP,0,6,6,8,8,99,.5,.5,2,2,3,3)* &
LinInt(BA_ALL,0,80,80,120,120,999,.5,.5,2,2,3,3)* &
LinInt((BA_SP/Max(BA_ALL,1)*100),0,25,25,50,50,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1
,2,2,3,3)* &
```

```
Min(Int(TPA_SP +0.9),1)

*BdwTsM=W Spruce Budworm/DF Tussock Moth
BdwTsM=(LinInt( &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,80,80,100,100,999,.5,.5,2,2,3,3)* &
LinInt(((SpMcDBH(2,ES,0,.1,99,4.5,250,0)+SpMcDBH(2,AF,0,.1,99,4.5,250,0)+ &
SpMcDBH(2,DF,0,.1,99,4.5,250,0)) &
/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,80,80,999,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(1,All,0,5,99,0,250,0),0,50,50,100,100,99999,.5,.5,2,2,3,3),&
0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,ES,0,0,99,0,250,0)+SpMcDBH(1,AF,0,0,99,0,250,0)+ &
SpMcDBH(1,DF,0,0,99,0,250,0)+0.9),1)

END

** For all bark beetle ratings if total stand BA < 40 ft2 rating will be low (1),
** if BA GE 40 rating unchanged from above calculation 2/27/2017

IF          0
_ESBTL NE 0
THEN
Compute           0
ESBtl=_ESBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_ESBtl,1))
End
EndIf

IF          0
_DFBtl NE 0
THEN
Compute           0
DFBtl=_DFBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_DFBtl,1))
End
EndIf

IF          0
_PPBtl NE 0
THEN
Compute           0
PPBtl=_PPBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_PPBtl,1))
End
EndIf

IF          0
_WPBtl NE 0
THEN
Compute           0
WPBtl=_WPBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_WPBtl,1))
End
EndIf
```

```
IF          0
_WBBtl NE 0
THEN
Compute           0
WBBtl=_WBBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_WBBtl,1))
End
EndIf

IF          0
_LPBtl NE 0
THEN
Compute           0
LPBtl=_LPBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_LPBtl,1))
End
EndIf

IF          0
_CBBtl NE 0
THEN
Compute           0
CBBtl=_CBBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_CBBtl,1))
End
EndIf

IF          0
_ESBTL EQ 0
THEN
Compute           0
ESBTL = 0
End
EndIf

IF          0
_DFBtl EQ 0
THEN
Compute           0
DFBtl = 0
End
EndIf

IF          0
_PPBtl EQ 0
THEN
Compute           0
PPBtl = 0
End
EndIf

IF          0
```

```
_WPBtl EQ 0
THEN
Compute           0
WPBtl = 0
End
EndIf

IF          0
_WBBtl EQ 0
THEN
Compute           0
WBBtl = 0
End
EndIf

IF          0
_LPBtl EQ 0
THEN
Compute           0
LPBtl = 0
End
EndIf

IF          0
_CBBtl EQ 0
THEN
Compute           0
CBBtl = 0
End
EndIf
```

B) Eastern Montana variant **********

```
COMMENT
Computes pest hazard ratings.
EM_Insect_Hazard_rating.kcp  - Forest Health Hazard Rating System   11/23/2018
For EM variant, Uses alpha species codes
R1 FHM Staff, derived these hazard ratings based on citations listed in
FHP Report "2018 Revised R1 Forest Insect Hazard Rating System User Guide for use
with
Inventory Data Stored in FSVeg and/or Analyzed with the Forest Vegetation Simulator"
Dec. 2018

Updates 07/05/2018 - For all moderate and high bark beetle ratings if total stand
basal area < 40 ft2
rating is low (1), if total stand BA is GE 40 ft2, rating is unchanged from above
calculation 2/27/2017
Compute variables _ESBTL, _DFBTL, _PPBTL, _WBBTL, _LPBTL, & _CBBTL are ratings prior
to the 40 ft2 total stand
basal area criteria being applied. Final ratings are displayed as ESBTL, DFBTL,
PPBTL, WBBTL, LPBTL & CBBTL.
```

```
COMPUTE keyword has a “0" in the first field indicating that the ratings will be
calculated every cycle.
End

COMPUTE           0

*ESBtl=Spruce Beetle
_ESBtl=(LinInt( &
LinInt(SpMcDBH(5,ES,0,10,99,0,250,0),0,12,12,16,16,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,100,100,150,150,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,ES,0,10,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,65,65,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,ES,0,0,99,0,250,0)+0.9),1)

*DFBtl=Douglas-fir Beetle
_DFBtl=(LinInt( &
LinInt(SpMcDBH(5,DF,0,9,99,0,250,0),0,10,10,14,14,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,100,100,250,250,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,DF,0,9,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,999,.5,.5,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,DF,0,0,99,0,250,0)+0.9),1)

*PPBtl=Ponderosa Pine (MPB/WPB)
_PPBtl=(LinInt( &
LinInt(SpMcDBH(5,PP,0,5,99,0,250,0),0,6,6,10,10,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,80,80,120,120,999,.5,.5,2,2,3,3)* &
LinInt((SpMcDBH(2,PP,0,5,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,40,40,65,65,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,PP,0,0,99,0,250,0)+0.9),1)

*WBBtl=Whitebark Pine/Limber Pine (MPB)
_WBBtl=LinInt(LinInt(13.54*SQRT((SPMCDBH(2,WB,0,5,99)+SPMCDBH(2,LM,0,5,99))/ &
Max((SPMCDBH(1,WB,0,5,99)+SPMCDBH(1,LM,0,5,99)),1)),0,7,7,12,12,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,40,40,45,45,999,.5,.5,2,2,3,3)* &
LinInt(((SpMcDBH(2,WB,0,5,99,0,250,0)+ SpMcDBH(2,LM,0,5,99,0,250,0))/ &
Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1)*100),0,25,25,50,50,999,.5,.5,2,2,3,3) &
,0,2,2,18,18,99,1,1,2,2,3,3) * &
Min(Int(SpMcDBH(1,WB,0,0,99,0,250,0)+SpMcDBH(1,LM,0,0,99,0,250,0)+0.9),1)

*LPBtl=Lodgepole Pine 5/2011 (MPB)
_LPBtl=(LinInt( &
LinInt(SpMcDBH(5,LP,0,5,99,0,250,0),0,7,7,8,8,99,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),00,80,80,120,120,250,250,999, &
      .5,.5, 2,  2,  3,  3, .5, .5)* &
LinInt((SpMcDBH(2,LP,0,5,99,0,250,0)/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,25,25,50,50,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,LP,0,0,99,0,250,0)+0.9),1)

*CBBtl=ComboMAX (MPB)
```

```
BA_SP =
SPMCDBH(2,WB,0,5,99)+SPMCDBH(2,LM,0,5,99)+SPMCDBH(2,LP,0,5,99)+SPMCDBH(2,PP,0,5,99)
BA_ALL = SpMcDBH(2,All,0,.1,99,4.5,250,0)
TPA_SP =
SpMcDBH(1,WB,0,0,99)+SpMcDBH(1,LM,0,0,99)+SpMcDBH(1,LP,0,0,99)+SpMcDBH(1,PP,0,0,99)
QMD_SP =
Max(SPMCDBH(5,WB,0,5,99),SPMCDBH(5,LM,0,5,99),SPMCDBH(5,LP,0,5,99),SPMCDBH(5,PP,0,5,
99),1)

_CBBtl=LinInt &
(LinInt(QMD_SP,0,6,6,8,8,99,.5,.5,2,2,3,3)* &
LinInt(BA_ALL,0,80,80,120,120,999,.5,.5,2,2,3,3)* &
LinInt((BA_SP/Max(BA_ALL,1)*100),0,25,25,50,50,999,.5,.5,2,2,3,3),0,2,2,18,18,99,1,1
,2,2,3,3)* &
Min(Int(TPA_SP +0.9),1)

*BdwTsM=W Spruce Budworm/DF Tussock Moth
BdwTsM=(LinInt( &
LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),0,80,80,100,100,999,.5,.5,2,2,3,3)* &
LinInt(((SpMcDBH(2,ES,0,.1,99,4.5,250,0)+SpMcDBH(2,AF,0,.1,99,4.5,250,0)+ &
SpMcDBH(2,DF,0,.1,99,4.5,250,0)) &
/Max(SpMcDBH(2,All,0,.1,99,4.5,250,0),1) &
*100),0,50,50,80,80,999,.5,.5,2,2,3,3)* &
LinInt(SpMcDBH(1,All,0,5,99,0,250,0),0,50,50,100,100,99999,.5,.5,2,2,3,3),&
0,2,2,18,18,99,1,1,2,2,3,3))* &
Min(Int(SpMcDBH(1,ES,0,0,99,0,250,0)+SpMcDBH(1,AF,0,0,99,0,250,0)+ &
SpMcDBH(1,DF,0,0,99,0,250,0)+0.9),1)

END

** For all bark beetle ratings if total stand BA < 40 ft2 rating will be low (1),
** if BA GE 40 rating unchanged from above calculation 2/27/2017

IF          0
_ESBTL NE 0
THEN
Compute           0
ESBtl=_ESBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_ESBtl,1))
End
EndIf

IF          0
_DFBtl NE 0
THEN
Compute           0
DFBtl=_DFBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_DFBtl,1))
End
EndIf

IF          0
```

```
_PPBtl NE 0
THEN
Compute           0
PPBtl=_PPBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_PPBtl,1))
End
EndIf

IF          0
_WBBtl NE 0
THEN
Compute           0
WBBtl=_WBBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_WBBtl,1))
End
EndIf

IF          0
_LPBtl NE 0
THEN
Compute           0
LPBtl=_LPBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_LPBtl,1))
End
EndIf

IF          0
_CBBtl NE 0
THEN
Compute           0
CBBtl=_CBBtl/(LinInt(SpMcDBH(2,All,0,.1,99,4.5,250,0),40,40,_CBBtl,1))
End
EndIf

IF          0
_ESBTL EQ 0
THEN
Compute           0
ESBTL = 0
End
EndIf

IF          0
_DFBtl EQ 0
THEN
Compute           0
DFBtl = 0
End
EndIf

IF          0
_PPBtl EQ 0
THEN
```

```
Compute           0
PPBtl = 0
End
EndIf

IF          0
_WBBtl EQ 0
THEN
Compute           0
WBBtl = 0
End
EndIf

IF          0
_LPBtl EQ 0
THEN
Compute           0
LPBtl = 0
End
EndIf

IF          0
_CBBtl EQ 0
THEN
Compute           0
CBBtl = 0
End
EndIf
```